Herbaceous Standing Crop as a Function of Seasonal Precipitation and Ponderosa Pine Overstory and Beef Production as a Function of Stocking Pressure and Peak Standing Forage Crop

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Forest Service, USDA

Rocky Mountain Forest and Range Experiment Station

Phil R. Ogden

Professor of Range Management

School of Renewable Natural Resources

University of Arizona

Tucson, Arizona 85721

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Early work was conducted by Donald A. Jameson and Henry A. Pearson. Warren Clary was responsible for the project during the latter years of the study. William H. Kruse was the range technician on the project throughout most of the study period and to Bill goes special credit and thanks for collecting the bulk of the data, data reduction, and maintaining the data in a useable form.

This publication was initiated at the request of Lawrence D. Garrett, Project Leader, Flagstaff, and made possible through Research Agreement Number 53-82FT-0-115. The objective is to review and summarize the Wild Bill data and to provide livestock production functions applicable for use in ECOSIM and other planning models.

INTRODUCTION

In the early 1960's, researchers involved with the Beaver Creek Pilot Watersheds recognized the need for developing livestock and timber production functions for a range of ponderosa pine overstories. These data would be available for use in multiple use models developed on the Beaver Creek Watersheds. After considering a number of alternatives, an area on the U.S. Forest Service Wild Bill Cattle Allotment, located 13 miles northwest of Flagstaff, Arizona, was selected as the location for the study. The research area became known as the Wild Bill Range.

Pearson and Jameson (1967) provided an information publication describing the area, study design, and early sampling on the Wild Bill Range. They stated that the objectives of the study were to determine:

"1. The effect of various tree overstories on quantity, quality, and composition of forage.

2. The relationship between beef and timber production at various tree overstories."

Numerous publications have covered various aspects of the study and have reported much of the data from the study. The purpose of this report is to analyze the combined information of these previous publications along with additional analyses of all the data, including some unpublished data from the latter years of the study. Also, an objective is to complete a summary report on the Wild Bill Range with emphasis on livestock production.

Table 1.--Monthly precipitation at Fort Valley, Arizona and long term normal precipitation.

Year	J	F	M	A	M	J	J	A	S	O	N	D	Tota
						Inches							
1961	1.13	.19	3.26	.42	.60	.28	1.99	5.54	1.68	1.56	.92	2.56	20.1
1962	2.86	3.20	1.16	.19	1.16	.69	2.39	1.50	1.60	1.20	1.15	.89	17.9
1963	.96	1.26	.91	1.61	.05	.02	.50	6.56	2.03	1.67	1.89	.26	17.7
1964	1.67	.20	3.08	2.66	.56	.26	3.46	3.84	1.81	.01	1.07	2.38	21.0
1965	2.46	2.12	2.59	5.59	2.43	.32	5.48	2.01	4.42	.13	3.92	5.82	37.2
1966	.90	1.46	1.48	.40	.09	2.06	3.37	2.66	1.03	.86	2.01	5.65	21.9
1967	1.21	T	1.05	1.68	.78	1.26	7.41	4.45	1.81	.84	.98	6.52	27.9
1968	1.11	.77	.88	2.71	.78	.26	2.60	3.08	.03	1.81	1.17	2.09	17.2
1969	4.73	4.21	3.34	.15	1.22	.12	2.92	2.57	1.68	1.20	1.85	.54	24.5
1970	.76	.31	7.14	.97	T	.05	3.45	3.58	2.26	.59	1.74	1.59	22.4
1971	.24	1.13	.32	.89	.83	.00	2.33	4.90	1.85	3.45	.24	2.47	18.6
1972	.00	.01	T	1.19	.12	3.25	2.84	3.52	.63	9.55	1.71	3.10	25.9
1973	1.87	3.20	6.57	1.46	.80	1.04	2.97	1.29	T	.38	2.07	.30	21.9
1974	2.84	.27	.77	.54	.05	T	1.94	1.74	.48	2.85	.75	.63	12.8
1975	.98	1.98	2.38	1.69	.89	.00	5.49	1.21	1.23	.26	2.00	.94	19.
1976	.21	3.91	1.59	2.30	2.37	.01	3.30	1.76	1.97	.52	.10	1.00	19.
1977	1.61	.70	.83	1.38	.80	1.21	1.99	1.89	1.30	1.11	.58	1.40	14.
1978	2.88	3.77	3.48	1.11	.31	T	2.04	2.24	.82	.72	3.91	3.62	24.
Dev.	.70	2.11	1.36	-.49	-.38	-.64	-.93	-1.22	-.87	-.70	2.58	1.39	2.
Normal[1]	2.18	1.66	2.12	1.60	.69	.64	2.97	3.46	1.69	1.42	1.33	2.23	21.

[1] Calculated from 1978 amounts and deviations from normal in 1978.

Data From: U.S. Department of Commerce 1961-78. Climatological Data-Arizona Vol. 65 No. 13-Vol. 82 No. 13. National Climatic Center, Federal Building, Asheville, North Carolina 28801

STUDY AREA RESEARCH METHODS

The Wild Bill Range pastures are located withith the ponderosa pine type with an understory dominated by Arizona fescue[1] and mountain muhly. The elevation averages 7,600 feet, and the average frost free period occurs from July 17 to September 19 (Pearson and Jameson 1967). Long term weather records are available from a weather station at Fort Valley, located about 5 miles southeast of the Wild Bill Range. Data from this station for 1961 to 1978 are given in Table 1. These data were utilized for analyses of the effect of seasonal precipitation on the amount of herbaceous standing crop grown on the Wild Bill pastures. The normal annual precipitation for Fort Valley is 22 inches.

The soils on the study area are derived from basalt parent material with the major portion of the pastures dominated by a moderately deep gravelly silt loam soil on 0 to 10% slopes. There are small inclusions of gravelly silt loam soil on 10 to 20% slopes and small inclusions of a gravelly silt loam soil with a higher degree of soil development than for the soil dominating the area. Soil permeability is slow to moderately rapid; the pH ranges from 6.0 to 7.4 (Capito 1962).

Pearson and Jameson (1967) described the ponderosa pine overstory on the Wild Bill area as an uneven-aged stand with some old trees and a high number of trees established in the favorable reproduction year of 1919. The understory vegetation is dominated (on the order of 90% by weight) by grasses with the dominants being Arizona fescue and mountain muhly. Bottlebrush squirreltail, pine dropseed, sedges, lupine, senecio, daisy, mullein, and thistle are other

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[1]Scientific names of plants are given in Appendix A.

species of importance. Browse is limited on the pastures except for scattered Fendler ceanothus. Ceanothus increased in abundance on Pasture 7 after a wild fire, May 9, 1967.

The Wild Bill Range was fenced into eight pastures, seven treatment pastures and one holding pasture (Fig. 1). Pulpwood and merchantable timber were harvested from all cleared and thinned pastures and the slash was piled and burned (Pearson and Jameson 1967).

Pasture 1 was clear cut, the slash pushed into piles and burned, and the area ripped and seeded with intermediate and crested wheatgrass and yellow sweet clover. This treatment was completed in 1962.

Pasture 2 also was clearcut, and the slash piled and burned in 1962, but the pasture was not seeded.

Pasture 3 was thinned to 20 square feet basal area with the slash piled by hand and burned. The treatment was completed in 1965.

Pasture 4 pine was thinned to 40 square feet basal area with hand piling and burning of slash completed in 1963.

Pasture 5 was thinned to 60 square feet of pine with hand piling of slash and burning completed in 1964.

Pasture 6 was thinned to 80 square feet basal area, and slash piling and burning were completed in 1964.

Pasture 7 was retained untreated. Basal area of pine was 110 square feet basal area.

On May 9, 1967 a wild fire burned the approximate area as shown on Figure 1. After this fire, the southwest portion of the holding pasture was sampled and designated as Pasture 8 to replace Pasture 7 as the unthinned pasture, but Pasture 8 was not fenced separately from the balance of the holding pasture.

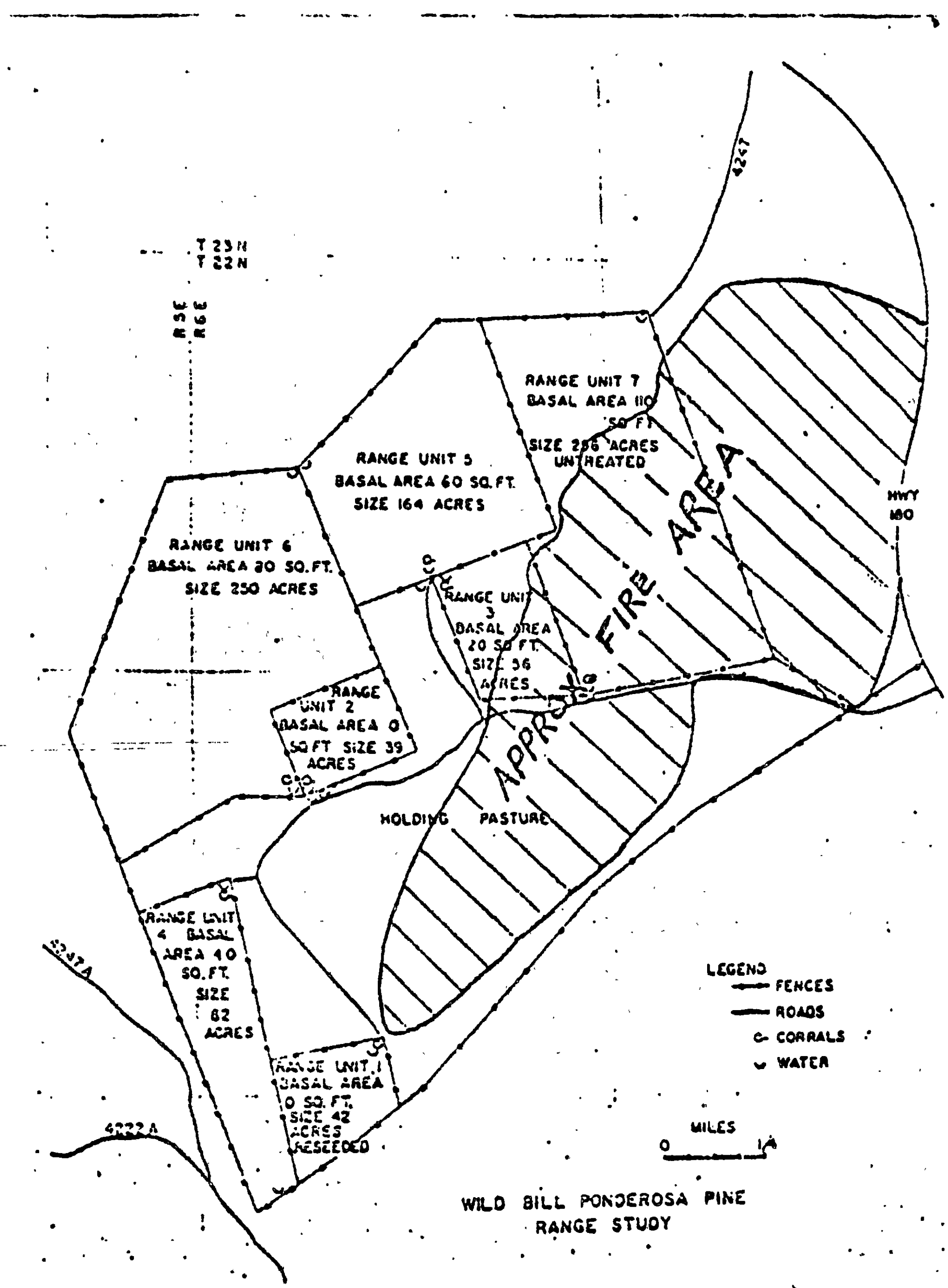

Figure 1.--General pasture layout of Wild Bill Study and the area burned over May 9, 1967.

Preliminary forage digestibility studies and phenology studies of Arizona fescue and mountain muhly were undertaken in 1963 and 1965 and these data have been published by Pearson (1964, 1967a, and 1967b). Herbaceous standing crop data were collected beginning in 1962. These data were reported by Pearson (1964), Jameson (1967), and Pearson and Jameson (1967) as a function of variability of basal area of ponderosa pine within unthinned stands. It was not until 1965 that thinning treatments were complete and all pastures were stocked with yearling cattle. Livestock data for the years 1965-71 and herbaceous standing crop data from 1964-74 are summarized in this current report as herbage and cattle weight gain production functions.

HERBAGE STANDING CROP

Sampling Variation

Vegetation weight determined at one or a few points in time underestimates true herbaceous production on a site; therefore, standing crop is used to describe vegetation weight data for the Wild Bill Range rather than production. Herbage standing crop was determined by clipping and weighing or estimating weight of individual plant species on 9.6 square feet plots. Fifteen cluster locations were randomly located in each pasture. Three permanent sample points were located at 50-foot intervals along a transect originating at the permanent cluster location. Caged and uncaged 9.6 square foot sample plots were paired at a new location annually in a systematic manner around each permanent sample point.

Standing crop disappearance associated with grazing was determined as the difference between species dry weight on caged and uncaged plots. Data from 1965 through 1968 were obtained by clipping plants in the caged plots to simulate

the grazed level of plants on uncaged plots at three times during the summer grazing period (approximately at 6-week intervals). The sum of the herbage removed at each of the three sample times plus the residue to ground level remaining at mid September is reported as standing crop. From 1969 through 1974, the data represent only a mid September measurement by clip and weigh and/or estimation by plant species for the caged plots (Pechanic and Pickford 1937). Disappearance was calculated as the difference between the paired caged and uncaged plots at this mid September sample date.

Utilizing the analysis of variance form given in table 2, the components of variance were calculated for total standing crop data for 1967 and 1970 (table 3), and representative statistics were calculated for grass standing crop (table 4) and total standing crop (table 5). The years 1967 and 1970 represent maximum and minimum production years respectively; and the variance associated with these years is indicative of the range of variance which can be expected in this study.

Table 2.--Analysis of variance form for herbaceous standing crop data for each Wild Bill Range pasture.

Source	Degrees of Freedom	Expected Mean Squares
Among Clusters	14	$\sigma w^2 + 3\ \sigma_A$
Within Clusters	30	σ^2_W
TOTAL	44	

Table 3.--Components of variance for total standing crop data for Wild Bill Pastures, 1967 and 1970.

Pasture	Year	s_W^2	s_A^2
1	1967	194,811	15,659
	1970	163,932	77,056
2	1967	440,444	240,739
	1970	79,887	31,749
3	1967	276,190	32,239
	1970	148,735	Negative
4	1967	497,276	Negative
	1970	112,777	42,966
5	1967	117,672	57,604
	1970	23,440	8,923
6	1967	159,966	16,099
	1970	26,954	Negative
7	1967	5,210	5,969
	1970	129,821	245,179

Table 4.--Mean standing grass crop per pasture for 1967 and 1970[1].

Pasture	Year	Mean lb/A	s[+]	CV[#] %	95% Confidence Interval lb/A	95% Confidence Interval % of Mean
1	1967	632	337	53.4	116	18.4
	1970	939	662	70.4	211	22.5
2	1967	824	1104	134.0	353	42.8
	1970	185	290	156.7	93	50.3
3*	1967	513	607	118.4	195	38.0
	1970	440	248	56.4	126	28.6
4	1967	548	569	103.9	190	34.7
	1970	329	506	153.7	162	49.2
5	1967	317	412	130.0	132	41.6
	1970	182	140	76.8	45	24.7
6	1967	310	422	136.2	135	43.5
	1970	136	127	93.6	45	33.1
7	1967	43	90	208.9	29	67.4
	1970	356	581	163.1	185	52.0

[1]Variation is based on cluster averages, 15 clusters per pasture.

*Portions of these pastures burned by a wild fire on May 9, 1967.

[+]Standard deviation.

[#]Coefficient of variation.

Table 5.--Mean total standing crop per pasture for 1967 and 1970[1].

Pasture	Year	Mean lb/A	s[+]	CV[#] %	95% Confidence Interval lb/A	% of Mean
1	1967	841	485	57.7	167	19.9
	1970	1128	629	55.7	201	17.8
2	1967	1414	1078	76.3	345	24.4
	1970	480	418	87.2	133	27.7
3[*]	1967	635	611	96.2	195	30.7
	1970	532	328	61.6	124	23.3
4	1967	686	567	82.6	225	32.8
	1970	426	492	115.4	157	36.9
5	1967	415	539	129.9	172	41.4
	1970	272	224	82.4	72	26.5
6	1967	364	456	125.4	146	40.1
	1970	182	160	87.8	53	29.1
7	1967	70	149	213.4	49	70.0
	1970	612	930	152.0	298	48.7

[1]Variation is based on cluster averages, 15 clusters per pasture.

[*]Portions of these pastures burned by a wild fire on May 9, 1967.

[+]Standard deviation.

[#]Coefficient of variation.

The component of variance for among clusters (s_A2) generally is small relative to the component of variance for within clusters (s_W2) (table 3). The major variation was among the sample locations. A major contributing factor to this variation is a characteristic spotty nature of the Arizona fescue-mountain muhly vegetation, especially with the disturbance involved in clearing and thinning the pastures. Also variance is associated with the inefficiency of the round, 9.6 square feet sample plots to adequately sample this spotty vegetation pattern.

Coefficients of variation ranged from 53% for grass standing crop on Pasture 1 in 1967 (table 4) to a high of 213% for the total standing crop on Pasture 7 in 1967 (table 5). Coefficients of variation for estimates of forb standing crops generally were much greater than for the grass or total standing crop.

Variability at the species level was so great that differences by species is difficult to interpret. For the two major grass species on Pasture 2 for 1967, the coefficients of variation were 29% ($\bar{x}$= 190 16/A) for Arizona fescue and 272% (223 16/A) for mountain muhly.

The variance in these data are representative of the variability often associated with range standing crop data and are discussed here to provide the reader with a feel for this background noise which must be considered during the analysis and interpretation of these kinds of data. Sample means are the best estimate of the population mean and data points tend to cluster about the sample mean. With the wide variation, however, occasional outliers are probable.

Annual Variation Within Pastures

The mean standing herbage crop, evaluated over time, is meaningful as an index to describe the influence of a treatment on the productivity of a site. Means for grass, forb, shrub, and total standing crop for the Wild Bill pastures for the period of 1964 to 1974 are given in table 6. In terms of total understory standing crop, the two cleared pastures had similar means, 1078 and 1088 pounds per acre, and these means represent the general level of understory standing crop which can be attained by clearing ponderosa pine on sites comparable to the Wild Bill Range. This amount is of the order of 200 pounds per acre greater than estimated by Ffolliott and Clary (1974) for a ponderosa pine site with no overstory and with a 22-inch annual precipitation.

The understory standing crop decreases with increasing level of timber overstory. This decrease of understory vegetation with increased timber overstory is well documented in the literature as shown in a bibliography prepared by Ffolliott and Clary (1972).

The factors contributing to yearly production variability are important for determining management strategies, especially at the variability influences site protection and forage availability for livestock and wildlife.

The maximum amounts of herbage standing crop on the Wild Bill pastures were recorded in the years of 1964, 1965, 1966, and 1967 (table 6). During these years the maximum levels observed were on the order of 60% higher than the mean for the pastures over the 1964-74 period. The minimum standing crop values for all pastures were observed mostly in 1970 and 1971 except low total standing crop was also observed for Pastures 3 and 5 in 1964 (table 6)

Table 6.--Average annual standing crop of grasses, forb, and shrubs by pasture for the Wild Bill Study, 1964-74.

Year	Grass	Forb	Shrub	Total	Grass	Forb	Shrub	Total
				lb/A				
	Pasture 1				Pasture 2			
1964	1205	92	T	1297	691	1181	T	1872
1965	939	34	3	975	541	485	6	1032
1966	1303	386	0	1689	525	836	0	1361
1967	632	195	12	840	824	590	0	1414
1968	714	270	8	994	340	828	1	1169
1969	766	61	5	833	394	250	1	645
1970	940	176	15	1131	187	297	T	484
1971	557	184	5	745	325	499	7	830
1972	590	580	21	1191	434	577	0	1011
1973	1086	252	8	1345	529	524	111	1164
1974	635	151	19	804	446	616	2	1063
Mean	852	218	8	1078	476	600	12	1088
	Pasture 3				Pasture 4			
1964	386	24	0	410	650	65	T	715
1965	554	36	T	590	505	96	1	603
1966*	572	67	0	638	457	145	0	602
1967	513	120	1	635	544	139	1	683
1968	461	88	10	559	342	32	3	377
1969	460	100	15	575	232	65	5	301
1970	442	83	11	535	331	95	4	430
1971	373	32	12	417	212	38	3	253
1972	402	113	25	540	251	116	1	368
1973	510	53	T	563	250	53	T	303
1974	434	79	5	518	340	50	5	394
Mean	463	72	7	546	375	80	2	457

Table 6.--Continued on page 2

Table 6.--Continued

Year	Grass	Forb	Shrub	Total	Grass	Forb	Shrub	Total
				lb/A				
	Pasture 5				Pasture 6			
1964	170	46	0	216	159	20	0	179
1965	448	134	T	582	270	41	0	311
1966	343	58	0	401	274	57	0	331
1967	325	90	T	415	310	52	2	364
1968	195	59	2	256	137	46	0	183
1969	173	60	1	235	168	68	0	235
1970	184	90	1	275	137	46	1	184
1971	172	50	0	222	119	28	1	148
1972	219	79	0	299	173	48	0	221
1973	222	92	0	315	181	60	3	244
1974	244	79	T	323	119	31	0	150
Mean	246	78	T	324	187	46	1	233
	Pasture 7				Pasture 8			
1964	47	11	T	58	--	--	-	--
1965	48	14	0	62	--	--	-	--
1966*	31	20	0	51	--	--	-	--
1967	43	26	1	70	141	21	1	163
1968	191	260	18	470	144	14	T	158
1969	267	144	52	464	190	45	0	234
1970	357	230	28	615	136	16	0	151
1971	371	228	30	629	141	17	0	157
1972	719	165	23	907	197	16	0	213
1973	523	65	35	624	168	22	2	193
1974	495	53	26	574	92	8	0	100
Mean					151	20	T	171
64-67	42	18	T	60				
68-74	418	164	31	612				

*A wild fire burned portions of Pasture 3 and severly burned Pasture 7 on May 9, 1967. Pasture 8 substituted for Pasture 7 as the unthinned pasture after 1967.

when treatments were not yet complete on these pastures. The minimum herbage standing crop amounts were on the order of 40% less than the mean for the 1964-74 period.

The interpretation of yearly variability of standing crop involves a consideration of climate, chiefly precipitation, time after treatment, the specific treatments, and livestock grazing influences. To present realistic production functions for a site, these influences should be considered and their influences separated to the extent possible. However, care must be taken, since effects often are an interaction of these factors which cannot easily be separated.

SEASONAL PRECIPITATION EFFECTS ON HERBACEOUS STANDING CROP

The evaluations of the effect of total amount and seasonal distribution of precipitation on the amount of understory vegetation was approached by dividing the seasonal precipitation into seasons which correspond to known phenological development of the major grass species present on the Wild Bill Range. Intermediate and crested wheatgrass are known to respond well to fall moisture. The shoot and root growth which these species make in the fall, contributes to their productivity the following spring (Ogden 1966). Therefore, September and October was considered as the fall growth season during which moisture would influence the following year of growth.

Pearson (1967b) showed that both Arizona fescue and mountain muhly initiate growth in the spring and flower in the summer. Arizona fescue produces flower stalks in July to early August and mountain muhly produces flower stalks in late August and early September. Thus, moisture stored in the soil during the winter combined with moisture received in the spring is considered necessary for spring growth. The winter and spring period is defined as November

Table 7.--Seasonal precipitation for 1962-74 in inches and as a percentage of the mean for the 1964-74 period, Fort Valley, Arizona.

Year	Previous Sept. + Oct. P_1 Amount Inches	%	Nov. - April P_2 Amount Inches	%	May + June P_3 Amount Inches	%	July + August P_4 Amount Inches	%
1962	3.24	.94	10.89 (10.00)*	1.14	1.85	1.25	3.89	.59
1963	2.80	.81	6.78	.77	.07	.05	7.06	1.07
1064	3.70	1.07	9.76	1.11	.82	.55	7.30	1.11
1965	1.82	.53	16.21 (10.00)	1.14	2.75	1.86	7.49	1.14
1966	4.55	1.32	13.98 (10.00)	1.14	2.15	1.45	6.03	.92
1967	1.89	.55	11.60 (10.00)	1.14	2.04	1.38	11.86	1.80
1968	2.65	.77	12.97 (10.00)	1.14	1.04	.70	5.68	.86
1969	1.84	.53	15.69 (10.00)	1.14	1.34	.91	5.49	.83
1970	2.88	.83	12.06 (10.00)	1.14	.05	.03	7.03	1.07
1971	2.85	.82	5.91	.67	.83	.56	7.23	1.10
1972	5.30	1.53	3.91	.45	3.37	2.28	6.36	.97
1973	10.18	2.94	17.91 (10.00)	1.14	1.84	1.24	4.26	.65
1974	.38	.11	6.79	.78	.05	.03	3.68	.56
1964-74								
Mean	3.46		11.53 (8.76)		1.48		6.58	
Norm.**	3.11	.90	11.12 (10.00)	1.14	1.33	.90	6.43	.98

*Ten inchs was the maximum amount allowed for the November-April period in regressions of standing herbage crop versus seasonal precipitation. The mean calculated using the 10-inch maximum was used to calculate the percent values.

**The normal precipitation is based on deviations reported for 1978 (table 1).

through April. Since excessive moisture during this time either runs off (Brown et al. 1974) or percolates below the grass root zone, ten inches of moisture was considered as the effective amount for this period. Excess moisture over 10 inches during the period of November to April was ignored for the multiple regression analyses.

May and June normally are dry months in northern Arizona with the normal for May and June for Fort Valley being .69 and .64 inches, respectively (table 1). This May-June period should affect the ability of Arizona fescue and mountain muhly growth in the early spring to carry over and produce additional growth and seed stalks in the summer. May-June was considered as a separate precipitation season of importance. The fourth season of moisture considered was the summer precipitation of July and August.

The seasonal moisture for Fort Valley is given in table 7 and is expressed both as the absolute amount and the seasonal amount expressed as a percentage of the mean precipitation for the 1964-74 period. Since there was a large difference in pasture productivity due to timber overstory differences, the standing crop of grass, forbs, and total were also expressed as a percentage of the mean for each respective pasture for the 1964-74 period. Multiple regression analyses were computed with Y as a percent of the mean standing crop versus the four seasonal precipitation amounts as percentage of the mean. The data for Pasture 1 seeded to the wheatgrasses was analyzed separately from the native Pastures 2-6. Data for Pasture 7 which was burned in 1967 and Pasture 8 for which the data did not span the full period were not used in the regression analyses. Regressions for Pasture 1 are based on n = 11 (11 years) and the equations for the native pastures are based on n = 55 (5 pastures x 11 years).

Table 8.--Coefficients and statistics for multiple regression equations expressing standing herbaceous vegetation as a function of seasonal precipitation

Equation no.	Standing crop*	Constant	Seasonal precipitation variables+ P_1	P_2	P_3	P_4	Statistics for equation R^2	P	Statistics for equations with all four precipitation variables R^2
1	YT_1	.54	.22	.24			.45	$p<.10$	.48
2	YG_1	.09	.17	.74			.55	$p<.05$	.57
3	YF_1	1.88	.34	-1.49	.27		.58	$p<.10$	.58
4	YT_2	.17		.44	.17	.21	.35	$p<.005$	.36
5	YG_2	.007		.51	.19	.29	.41	$p<.005$	.43
6	YF_2	.46		.22	.18	.15	.14	$p<.10$	.14

*Standing herbaceous vegetation crop as a percentage of the mean for each pasture for the record 1964-74 (Table 6).

YT_1 = Total herbaceous standing crop, pasture 1.

YG_1 = Gross standing crop, pasture 1.

YF_1 = Forb standing crop, pasture 1.

YT_2 = Total herbaceous standing crop, pastures 2-6.

YG_2 = Gross standing crop, pastures 2-6.

YF_2 = Forb standing crop, pastures 2-6.

+Seasonal pr[illegible]pitation as a percentage of normal as defined i[illegible]able 7.

The coefficients and statistics for multiple regression equations which resulted from these analyses are the six equations shown in table 8.

Fifty Five percent of the variability in grass standing crop for the seeded (Pasture 1) and 41% for the native pastures (Pastures 2-6) was accounted for by equations (2) and (5) respectively. Total standing crop and forbs on Pasture 1 also showed that a reasonably good proportion of the annual variability was accounted for by seasonal moisture. Only for the forb component on the native pastures did the regression equation (6) explain a low amount (14%) of the annual variability.

From equations (1-6), an estimated standing crop of grass, forbs, or total may be calcultated as a percentage of the mean. This value multiplied by the actual mean for each pasture for the 11 years provides an estimated standing crop value adjusted for seasonal precipitation. As an example, for the native pastures for 1964, the calculations would be as follows with seasonal precipitation values from table 7 and using equations (5):

$$Y_{G_2} = .007 + .51(1.11) + .19(.55) + .29(1.11) = 1.00$$

Since Y_{G_2} is 1.00, 1964 can be considered an average year for grass growth on the Wild Bill native pastures. Comparison of the seasonal normal precipitation and the 1964-74 means (table 7) show that the normal P_1, P_2, P_3, P_4 were .90, 1.14, .90, and .98 when referenced to the 11-year means, which when put into equations (1) - (6) result in little difference between the 11-year mean and the long-term normal precipitation (table 9).

Estimates of grass and total standing crop values for the wheatgrass pasture and for the native vegetation pastures are given in table 9. Standing grass and total crop estimates are expressed as a percentage of the mean for each pasture and

Table 9.--Estimates of grass and total standing crop as percentage of the pasture means for 1964-74[1]

Year	Pasture 1 (Wheatgrasses)		Pasture 2-6 (Native Vegetation)	
	Grass (Y_{G_1})	Total (Y_{T_1})	Grass (Y_{G_2})	Total (Y_{T_2})
	%	%	%	%
1962	1.09	1.02	1.00	1.01
1963	.80	.90	.72	.74
1964	1.09	1.04	1.00	.99
1965	1.02	.93	1.27	1.23
1966	1.16	1.10	1.13	1.11
1967	1.03	.93	1.37	1.28
1968	1.06	.98	.97	.97
1969	1.02	.93	1.00	1.00
1970	1.07	1.00	.90	.90
1971	.73	.88	.77	.79
1972	.68	.98	.95	.96
1973	1.43	1.46	1.01	1.02
1974	.69	.75	.57	.64
Normal	1.09	1.01	1.04	1.03

[1]Calculated from equations 1, 2, 4 and 5 (Table 8).

standing crop. Winter and spring moisture (P_2) is the major seasonal moisture influencing both the wheatgrass and native grass amounts of standing crop. However, the previous fall moisture (P_1) combines with this winter and spring precipitation to produce the wheatgrass crop. It is the May-June (P_3) and summer precipitation (P_4) which combine with the winter and early spring moisture to produce the native grass standing crops. For example, the best producing year for the wheatgrass pasture was 1973, but 1967 was best for the native pastures (table 9).

LIVESTOCK USE EFFECTS ON HERBACEOUS VEGETATION

When the mean standing crop values for 1964-1974 for each pasture (table 6) are multiplied by yearly percent of standing crop as estimated by equations 1-6 (table 9), an estimated standing crop value is obtained. Estimated and measured amounts of standing grass crop for Pastures 1 and 2 are plotted in Figure 2. Measured values of grass standing crops expressed as a percentage of the estimated value are given in table 10.

The high measured standing crop of the wheatgrassess in 1964-66 relative to estimated values (Fig. 2) most likely reflect the early years burst of high production which is typical of young seedings. The low standing crop of wheatgrasses on Pasture 1 in 1967 and 1968 can be explained by the high utilization levels of 59 and 62% in 1966 and 1967, the years preceeding the decreased measured crop relative to the estimated, along with a natural decrease following the initial years of high production. Reduced grass production following a year or years of heavy utilization or clipping is documented by the author (Ogden 1980). Comparisons of measured grass standing crop with estimated values for Pastures 4 and 5 show the measured crop to be 62 to 71% of the estimated amount in years following utilization in excess of 40%.

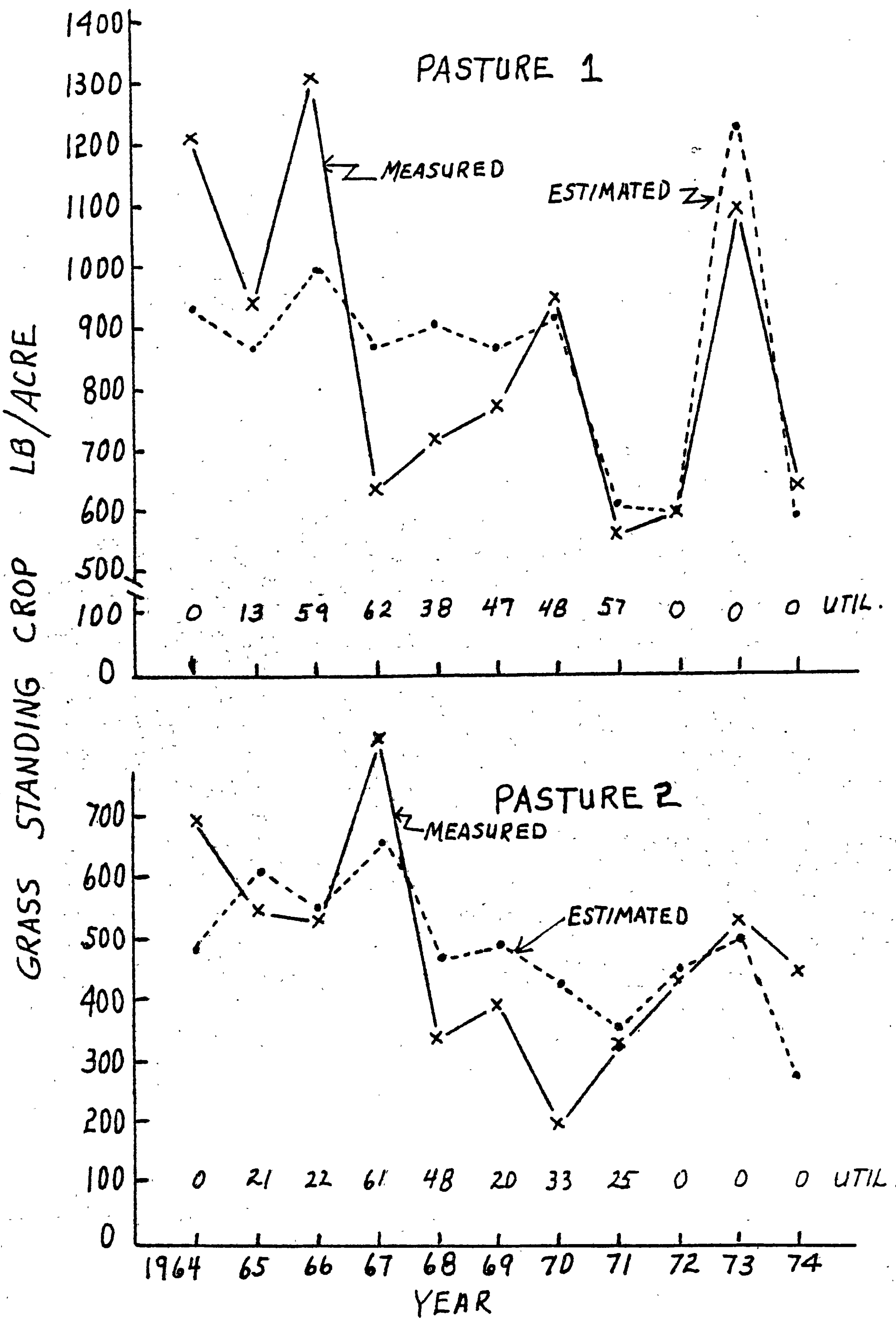

Figure 2.--Measured and estimated standing grass crop for Pastures 1 (cleared and seeded to wheatgrasses) and Pasture 2 (cleared, with native vegetation understory) on the Wild Bill Range, 1964-74. The estimated values represent the standing crop predicted by seasonal precipitation and 11-year pasture mean standing crop.

Table 10.--Percentage utilizations of grass and measured standing grass crop as a percent of estimated grass crop

	Pasture Number											
	1		2		3		4		5		6	
	Use	Crop	Use	Crop	Use	Crop	Use	Crop	Use	Crop	Use	Crop
Year	%	%	%	%	%	%	%	%	%	%	%	%
1964	0	130	0	145	0	83	0	173	0	69	0	85
1965	13	108	21	89	19	94	20	106	10	144	16	114
1966	59	132	22	98	18	109	36	108	20	123	6	130
1967	62	72	61	126	0	81	19	106	33	96	22	121
1968	38	79	48	74	0	103	50	94	42	82	53	76
1969	47	88	20	83	16	99	32	62	27	70	26	90
1970	48	103	33	44	33	106	28	98	18	83	20	82
1971	57	90	25	89	46	104	41	73	37	91	26	83
1972	0	102	0	96	0	91	0	71	0	94	0	97
1973	0	89	0	110	0	109	0	66	5	89	0	96
1974	0	108	0	165	0	164	0	159	0	174	0	111

The general effect of livestock utilization on the standing grass was to reduce the amount of standing grass crop relative to that estimated as a function of seasonal precipitation when grass utilization was on the order of 40 to 60% in the year previous to measurement of standing crop. The measured standing grass crops on all pastures in 1974 were higher than the estimated amount (table 10), for this year of low precipitation for all seasons. Effects of three years of no grazing and a possible failure of the seasonal precipitation equations to adequately predict the effects of this year of poor moisture at each season are likely confounded in these results.

No major plant composition changes occurred over the course of the Wild Bill grazing studies which could be attributed to livestock grazing. Crested wheatgrass did decrease in composition on Pasture 1 during the course of the study (table 11) and this decrease was accompanied by an increase in composition of intermediate wheatgrass and an increase in Erigeron divergens and Senecio. Senecio also increased in composition on Pasture 2, from an average of 1% in 1965-67 to 21% in 1972-74. Verbascum thapsis decreased in composition approximately the amount which Senecio increased (table 11). Orchard grass and Fendler ceanothus increased in composition following the wild fire on Pasture 7.

EFFECT OF CLEARING AND THINNING TREATMENTS ON UNDERSTORY VEGETATION

The clearing of ponderosa pine and burning the slash on Pastures 1 and 2 were very severe treatments which created considerable amounts of bare area. Slash burning on thinned pastures also created bare patches where the slash piles were burned. Parker 3-Step Transects established on the pastures in 1965 and read in 1965, 1966, 1967, and 1968 show that frequency of forage plants on the pastures was low (table 12) and did not show any dramatic increase in frequency during these four years. The sparse and spotty nature of the

Table 11.--Percentage composition of herbage standing crop for Wild Bill pastures expressed as means for three periods, 1965-67, 1968-71, and 1972-74.

Species	Pasture 1			Pasture 2			Pasture 3			Pasture 4		
	1965 to 1967	1968 to 1971	1972 to 1974	1965 to 1967	1968 to 1971	1972 to 1974	1965 to 1967	1968 to 1971	1972 to 1974	1965 to 1967	1968 to 1971	1972 to 1974
Agropyron cristatum	24	18	8	--	--	--	--	--	--	--	--	--
Agropyron intermedium	46	58	57	--	--	--	--	--	--	--	--	--
Blepharoneuron tricholepis	1	T	T	2	1	2	T	T	T	2	2	3
Carex spp.	1	T	1	3	3	7	12	6	10	4	3	10
Dactylis glomerata	--	--	--	--	--	--	T	1	1	--	--	--
Festuca arizonica	2	1	T	13	7	12	38	37	41	41	48	34
Hordeum jubatum	0	0	T	2	4	2	0	0	0	0	0	0
Muhlenbergia montana	6	1	1	18	9	11	21	26	14	23	22	16
Poa fendleriana	0	T	0	1	T	1	2	2	4	1	T	2
Sitanion hystrix	2	T	1	7	8	7	14	10	10	9	5	13
Other grasses	1	3	1	4	10*	3	1	2	T	1	2	0
Total grasses	83	81	69	50	42	44	88	84	80	81	82	78
Chenopodium spp.	0	T	1	2	1	1	T	T	T	T	0	0
Cirsium spp.	2	1	1	8	3	8	3	2	1	1	1	1
Conyza schiedeana	5	7	7	3	12	T	T	2	1	1	1	1
Erigeron divergens	1	2	7	4	6	2	0	T	T	T	T	T
Erigeron flagellaris	0	T	T	3	8	2	1	1	1	T	1	T
Lupinus spp.	T	0	0	2	2	7	1	2	6	3	2	3
Potentilla hippiana	0	T	T	0	T	T	T	0	0	2	4	2
Potentilla thurberi	0	T	T	T	T	1	0	T	0	T	3	6
Senecio spp.	1	5	7	1	11	21	T	T	0	1	1	T
Verbascum thapsis	5	T	5	21	7	2	2	3	2	8	1	1
Vicia americana	0	T	0	T	T	T	T	1	1	T	T	2
Other forbs and sum of traces	3	3	1	6	10	9	5	3	3	3	3	5
Total forbs	17	18	29	50	58	53	12	14	15	19	17	21
Total shrubs	T	1	2	T	T	3	T	2	5	T	1	1

*Mostly Muhlenbergia minutissima

Table 11.--Continued

Species	Pasture 5			Pasture 6			Pasture 7			Pasture 8		
	1965 to 1967	1968 to 1971	1972 to 1974	1965 to 1967	1968 to 1971	1972 to 1974	1965 to 1967	1968 to 1971	1972 to 1974	1965 to 1967	1968 to 1971	1972 to 1974
Blepharoneuron tricholepis	2	3	2	3	2	5	1	T	T	3	4	3
Carex spp.	11	11	18	9	10	18	13	11	14	6	7	12
Dactylis glomerata	--	--	--	--	--	--	3	19	23	0	T	0
Festuca arizonica	35	35	24	33	30	18	19	3	3	25	31	28
Hordeum jubatum	0	0	0	0	0	0	0	1	T	0	0	0
Muhlenbergia montana	11	9	7	23	20	19	10	6	14	48	39	39
Poa fendleriana	4	1	4	1	1	3	1	2	4	0	1	1
Sitanion hystrix	17	15	16	15	12	13	17	7	17	4	6	6
Other grasses	0	0	1	1	1	1	2	3	1	2	0	2
Total grasses	80	74	72	85	76	77	66	52	76	88	88	91
Chenopodium spp.	1	0	0	0	0	0	T	3	T	0	0	0
Cirsium spp.	2	T	1	4	2	1	T	2	1	0	T	1
Conyza schiedeana	0	0	0	T	0	0	1	10	T	0	T	1
Erigeron divergens	0	T	0	T	T	T	0	2	T	0	T	T
Erigeron flagellaris	1	6	2	2	7	3	4	3	T	1	2	1
Lupinus spp.	10	12	21	3	9	13	19	2	1	4	2	3
Potentilla hippiana	0	0	0	T	1	T	0	0	0	T	T	T
Senecio spp.	T	T	T	T	T	T	T	1	0	T	T	T
Verbascum thapsis	2	1	T	T	T	0	1	8	6	0	0	0
Vicia americana	1	2	1	1	1	1	2	T	1	T	1	T
Other forbs and sum of traces	3	5	3	5	4	5	6	11	3	6	7	4
Total forbs	20	26	28	15	24	23	33	42	12	11	12	9
Total shrubs	T	T	T	T	T	T	1	6	12	1	T	T

Table 12.--Vegetation condition ratings (1965) and percentage frequency of forage plants on Wild Bill pastures 1965-68.[1]

Pasture no.	Number of transects	Number of transects by condition				Percentage frequency of forage plants by years			
		good	fair	poor	v. poor	1965	1966	1967	1968
1	8	4	3	1	0	8.8	10.4	10.0	12.4
2	13	1	0	4	8	4.8	5.7	6.5	6.2
3	14	1	2	11	0	6.1	5.2	7.8	8.2
4	15	0	7	8	0	5.3	5.3	7.9	5.9
5	15	1	2	12	0	4.9	4.5	6.2	5.6
6	14	1	0	9	4	4.5	3.6	4.8	4.7
7	15*	0	1	9	5	2.4	1.4	0.6	2.9

[1]Data based on Parker 3-step condition and trend transects.

*Frequency data based on 7 transects.

vegetation on the pastures were chief contributing factors to the high proportion of poor condition ratings for transect locations within the pastures.

Grasses, with Arizona fescue and mountain muhly as the dominants, were the major understory vegetation on all treatments over all years except for Pasture 1, where wheatgrasses were seeded to replace the native grasses and for Pasture 2 where the treatment was so severe that considerable areas of bare ground were created and forbs occupied these areas rather than grasses. The clearing treatment on Pasture 2 increased total herbaceous standing crop but grass composition averaged 50, 42, and 44% grass for the years 1965-67, 1968-71, and 1972-74, respectively (table 13). Grass composition of vegetation in open areas of untreated ponderosa pine stands were 94 and 97% for 1962 and 1972-74 data, respectively (table 14). These data illustrate that a zero basal area of ponderosa pine resulting from clearing such as on the Wild Bill Pasture 2 does not create the same situation in terms of understory vegetation as occurs in natural openings in ponderosa pine vegetation, even 11 years following the treatment. The forb component averaged half or more of the vegetation on the cleared pasture throughout the study. Arnold's (1953) conclusion was similar to these results.

Comparisons among the grass composition of thinned pastures (table 13) with areas of similar basal areas within unthinned ponderosa pine stands (table 14) show slightly less composition of grass on the thinned pastures than on areas of comparable basal area within unthinned pine. This higher proportion of forbs on the thinned areas as compared to unthinned areas reflects bare areas created in the thinning and slash disposal treatments which did not readily become revegetated to grass.

Table 13.--Average basal area and mean percentage grass composition by weight on the Wild Bill pastures for three periods from 1964 to 1974.

Pasture no.	1965 to 1967 Basal* area sq ft/A	1965 to 1967 Grass composition %	1968 to 1971 Basal area sq ft/A	1968 to 1971 Grass composition %	1972 to 1974 Basal area sq ft/A	1972 to 1974 Grass composition %
1	0	83	0	81	0	69
2	0	50	0	42	0	44
3**	21	88	24	84	30	80
4	28	81	34	82	48	73
5	50	80	52	74	63	72
6	62	85	63	76	79	77
7**	120	66	50	52	60	76
8***	106	88	109	88	127	91

*Basal area of ponderosa pine overstory as measured in 1965, 1969, and 1973.

**Pastures 3 and 7 partially burned over May 9, 1967. The fire was mainly a ground fire in thinned Pasture 3 but crowned out and greatly reduced the overstory tree cover of Pasture 7.

***Pasture 8 added to replace Pasture 7 after the burn. Data are for 1967-74.

Table 14.--Percentage grass composition of the understory herbaceous standing crop under various natural basal areas of ponderosa pine.

Basal area sq ft/A	Year 1962	Mean for 1972-74
0	94	97
10	90	96
20	97	94
30	91	93
40	87	95
50	81	92
60	89	93
70	88	88
80	70	91
90	84	91
100	80	89

The five sets of data given in Figure 3 as total herbaceous standing crop as a function of ponderosa pine basal area, all for the Wild Bill area, show that data for any specific year for untreated areas can vary greatly from the mean data for pastures.

The 1962 data are low estimates of total standing crop for the gravelly silt loam and 22-inch precipitation site. As predicted by the amount and seasonal distribution of precipitation, the year of 1962 was an average year for grass production (table 9). Therefore, poor moisture in this year does not explain the low measured amount of standing crop.

The 1972 data in Figure 3 are for a year when the estimated total standing crop based on seasonal precipitation should be slightly less than average, the 1973 data slightly over average, and the 1974 data only 53% of average (table 9). Yet, the first two sets of data provide much higher estimates of standing crop compared to the means for the Wild Bill pastures which should closely represent an average year and the 1974 data provide data similar to the means for the Wild Bill pastures despite the very dry year.

The reasons why standing crop data on ungrazed and unthinned ponderosa pine areas is higher than for the Wild Bill data can not be explained fully. A reasonable hypothesis seems to be that the clearing and thinning treatments on the Wild Bill pastures created bare areas which did not become revegetated to native grasses within the 11 years following treatments.

If the objective is to estimate understory standing crop as a function of pine basal area on an unthinned and ungrazed area, the applicable production function might best be represented as an average of the 1972 and 1973 data presented in Figure 3, as these data represent near average precipitation years. The Wild Bill pasture data would represent the situation following timber harvesting activities.

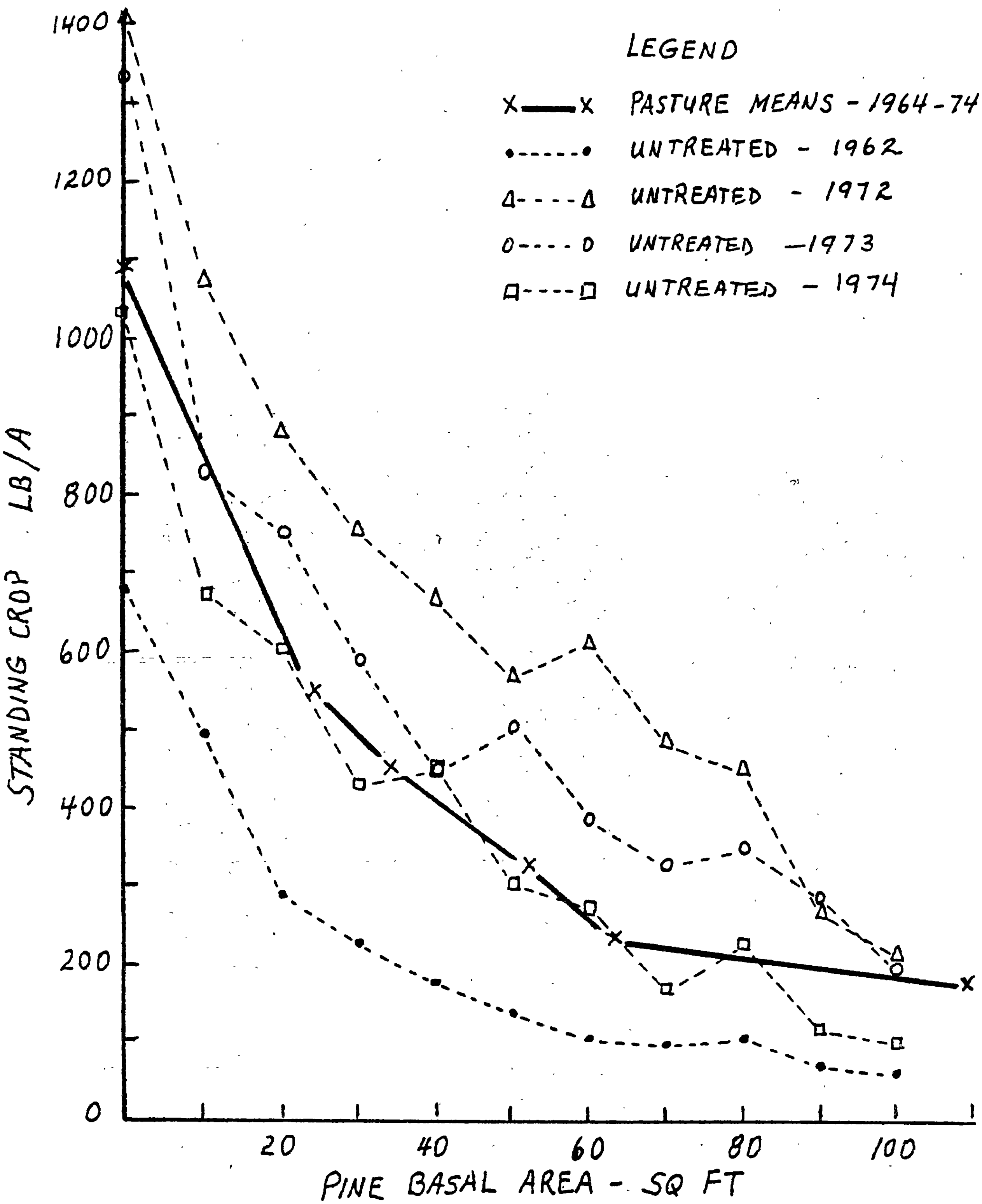

Figure 3.--Total standing herbaceous crop expressed as a function of pine basal area for the Wild Bill pastures and for untreated pine stands.

The reduction of pine basal area on Pasture 7 due to the wild fire of May 9, 1967 indicates that a separate understory production function may be necessary when basal areas changes are due to fire especially when areas are seeded after the burn. Orchard grass was seeded into the ashes following the burn, and this species and Fendler ceanothus (a shrub) increased in composition after the fire on this pasture (table 11) as total standing crop increased (table 6).

STANDING HERBACEOUS CROP AS A MEASURE OF FORAGE

Utilization in the Wild Bill study was determined by the use of paired plots, one grazed and the other caged. Difference between caged and uncaged standing crop is best described as disappearance associated with grazing and is not to be confused with forage intake. Utilization expressed as a percentage of the standing crop determined from caged plots is a measure of the net effects of forage intake, trampling and other grazing effects, growth, regrowth, and natural losses during the grazing season.

A review of the Wild Bill utilization data showed that variability in utilization at the species level was so large that the discussion is best handled by forage class. The relationship between utilization of forbs and utilization of grasses over the 1965-71 period for the Wild Bill pastures is shown in Figure 4. The regression line of forb use versus grass use was calculated excluding two outlier data points identified in Figure 4 as 1-67 and 1-71. There was 73% use of forbs when 62% use for grass was measured on Pasture 1 in 1967 and 1% use on forbs when grass use was 57% on Pasture 1 in 1971. Outliers represent changes in forb composition over years on Pasture 1 and also difficulty in sampling of a very diverse forb stand to obtain precise values. Forbs do provide forage for livestock and when abundant should be considered in this context.

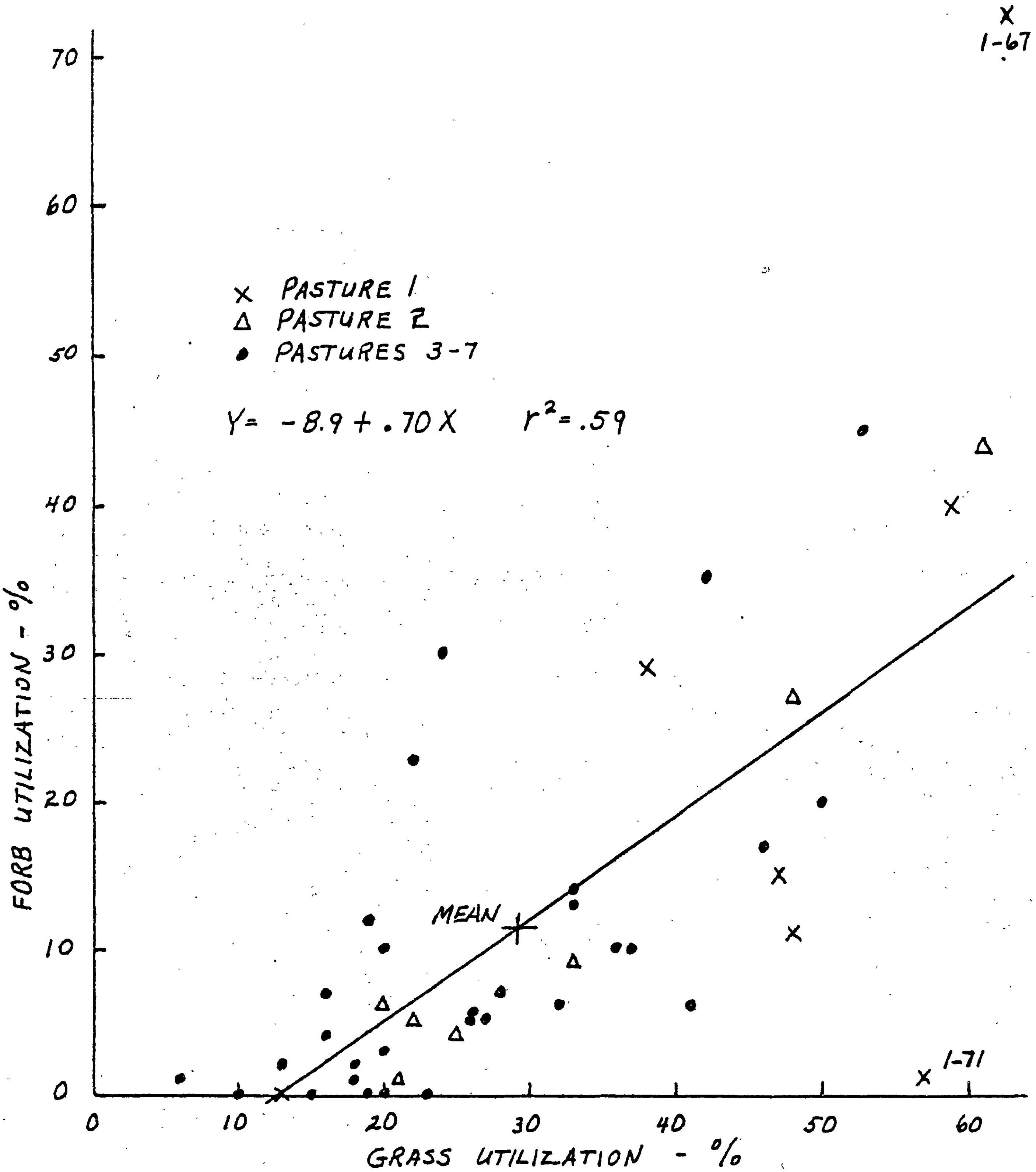

Figure 4.--Relationship of utilization of forbs and utilization of grass on the Wild Bill pastures, 1965-71.

As a general consideration for the Wild Bill Study, the mean utilization of forbs was 12% when grass use was 29%. The ratio of 12% to 29% is 41%.

For the situation which prevailed on the Wild Bill pastures with the general plant composition given in table 11, the forb standing crop was considered about 40% as effective for forage as grasses at 30% utilization of the grasses. Light utilization of grasses reduces the importance of forbs as forage and heavy utilization increased the relative amount of forbs utilized as forage. For instance, at 50% use on grasses there was about 26% use on forbs, or a relationship of forbs showing about 50% as much disappearance as grass at this level of grass utilization. Since average utilization of grass on the Wild Bill study pastures was near 30%, 40% of the forb standing crop was considered as forage when analyzing livestock production as a function of grazing pressure.

DISAPPEARANCE OF STANDING CROP PER YEARLING DAY OF USE

The difference in herbaceous standing crop between caged and uncaged plots at the end of the grazing season was calculated as disappearance per yearling day of use by pasture and is displayed in table 15. The data show some extreme outliers due to over- or under-estimates of forage standing crop or possible bias against selection of paired plots on bare areas.

Overall, the mean standing crop disappearance was 10 pounds per yearling day for the late May to mid September grazing season on the Wild Bill pastures. The mean of beginning and ending weights of yearlings on the pastures in 1965, 1966, and 1967 abd 472 pounds. Heavier yearling were grazed during the last four years of 1969-71, and their average mid season estimate of weight was 550 pounds. The forage disappearance was on the order of 2% of the yearling body weight per day.

Table 15.--Average difference in forage weight on caged plots and grazed plots on the Wild Bill pastures expressed as pounds per yearling day of use.

Year	Pasture 1	2	3	4	5	6	7	Mean
1965	7.6	7.5	13.7	10.0	13.4	13.2	5.5	10.1
1966	25.1	7.9	9.1	11.0	7.0	3.0	7.3	10.1
1967	12.7	16.8	----	12.0	7.5	7.2	----	11.2
1968	14.5	16.7	----	10.3	7.6	7.6	----	11.3
1969	14.0	5.1	6.4	5.9	4.8	6.0	----	7.0
1970	19.9	4.5	8.2	10.6	5.7	6.5	8.7	9.2
1971	17.5	8.9	11.1	11.0	10.0	7.1	10.7	10.9
						Mean		10.0

LIVESTOCK PRODUCTION FUNCTIONS AND APPLICATION TO ECONOMIC ANALYSES

Beginning in 1965, all pastures of the Wild Bill Range were stocked with yearling heifers to obtain approximately 40% utilization on Arizona fescue and 35% on mountain muhly. This first year, 4 to 6 animals were weighed onto each pasture and weiahed at intervals during the season. Additional unweighed animals were added to each pasture to obtain the desired utilization. Dates on and off, livestock class, number of animals, and average weight of the animals are given in table 16. Yearlings were weighed periodically during the summer in 1966 and 1967. For the years 1968-71, only initial and final weights were obtained, and it is the initial and final weight data for each pasture for all years of the study which were analyzed and which are reported in this report.

The yearling heifers which grazed the pastures in the 1965-67 years were furnished by a single operator. These heifers were smaller and more nervous than the yearling steers and heifers furnished by other operators in 1968-71. Average gain per day for the animals on the pastures from 1965-67 ranged from 1.01 to 1.24 pounds per day, whereas gains during the last four years of the study averaged 1.44 to 1.64 pounds (table 17). These differences in potential for gain greatly influenced the production functions for the livestock; thus, data were handled separately for these two periods.

Gain per animal was obtained from animals which were weighed onto the pastures and which remained on the pastures throughout the season to be weighed off at the end of the season. Average gains per day were calculated from these data. These data were based on as few as four animals for some pastures and years to as many as 30 animals. The precision and accuracy of the data vary greatly among pastures and among years due to differing aminal characteristics,

Table 16.--Average livestock weights at beginning and end of grazing season on Wild Bill pastures*

Year	Livestock class	Number of animals per pasture weighed on and off	Date on pastures	Lbs. ave. wt. on	Date off pastures	Lbs. ave. wt. off
1965	Yearling heifers	4 - 6	June 4	421	Sept 24-Oct 2	561
1966	Yearling heifers	4 - 13	May 27	413	Sept 16-29	535
1967	Yearling heifers	3 - 13	May 26	390	Sept 22-28	511
1968	Yearling steers	9 -30	June 6	462	Sept 17	617
1969	Yearling heifers and steers	7 - 15	May 27	475	Oct 9	668
1970	Yearling heifers and steers	7 - 14	May 27	460	Oct 12	676
1971	Yearling heifers and steers	4 - 13	May 25	411	Oct 8	632

*Weights are averages of pasture means.

Table 17.--Stocking rate, stocking pressure, and average daily gain in pounds for yearling cattle grazed on the Wild Bill pastures, 1965-71

	Pasture Number							
Year	1	2	3	4	5	6	7	Mean
				Stocking Rate Yearling Days/Acre				
1965	16.0	16.3	7.8	10.0	3.2	3.3	2.0	8.4
1966	37.0	19.7	11.6	16.4	10.9	6.0	1.8	14.8
1967	42.6	45.3	---*	10.0	16.1	10.8	---*	25.0
1968	24.3	23.3	---	17.3	13.7	12.2	---	18.2
1969	26.4	18.2	13.1	13.5	10.4	8.0	---	14.9
1970	23.8	19.9	19.5	9.5	6.2	4.4	6.1	25.0
1971	18.4	11.6	16.1	8.3	6.9	4.5	6.0	10.3
				Stocking Pressure Yearling Days/100 Pounds of Standing Forage				
1965	1.7	2.2	1.4		0.6	1.2	3.7	1.8
1966	2.5	2.3	1.9	3.2	3.0	2.0	4.6	2.8
1967	6.0		---	1.7	4.5	3.3	---	4.0
1968	3.0	3.5	---	4.9	6.3		---	5.1
1969	3.3	3.7	2.6	5.2	5.3	4.1	---	4.0
1970	2.4		4.1	2.6	2.8	2.8	1.4	3.2
1971	2.9	2.2	4.2	3.7	3.6	3.5	1.3	3.1
				Pounds Average Daily Gain/Day				
1965	1.50	1.32	1.53		1.50	1.40	.72	1.24
1966	1.07	1.59	.88	.96	.93	1.31	.60	1.05
1967	.72		----	1.47	1.08	1.29	----	1.01
1968	1.78	1.70	----	1.35	1.29		----	1.52
1969	1.61	1.58	1.57	1.21	1.34	1.35	----	1.44
1970	2.04		1.56	1.31	1.47	1.50	1.80	1.63
1971	1.67	2.03	1.40	1.33	1.48	1.50	2.06	1.64

*Pasture 3 not grazed the two years and Pasture 7 not grazed for 3 years following the May 9, 1967 wild fire.

varying animal numbers, and variability in measures of herbage standing crop. The production functions do indicate trends and relationships which should be good for general models and planning. They cannot be utilized to predict individual case responses with any degree of precision or accuracy.

Total yearling days on each pasture was calculated by summing the product of number of animals on the pasture and the number of days they were on the pasture. The day weighed onto the pasture and the day weighed off were not counted as grazing days. Days were calculated to date of standing crop data collection for those years when these data were collected before livestock removal from the pastures to provide the stocking pressure relationship between animals and vegetation data. This calculation accounts for slightly lower average estimate of yearling days per acre for the pastures than that reported by Clary, Kruse, and Larson (1975). Weight per animal, however, is for the complete grazing season. Stocking rates and stocking pressure are given in table 17 for each pasture for each year of the Wild Bill grazing studies.

Comparison of livestock performance by pasture treatments is not possible because these comparisons are confounded by differences in stocking rate and forage amount among the pastures. Pearson (1973) showed for the 1965-67 livestock data that average daily gain declined with increased level of utilization. A plot of the 1968 to 1971 data, however, showed a relatively poor fit of daily gain versus utilization. Yet, numerous studies have shown a linear relationship of the form $Y = a - bX$ for average daily gain versus stocking rate or some index associated with stocking rate. Hart (1980) referenced seven studies which substantiate this relationship. Stocking rate on the Wild Bill pastures is very much confounded with differences in availability of forage per pasture. Bement (1969) proposed that the individual animal gains per acre were best estimated as

a function of forage remaining on the grazed pastures at the end of the grazing season, and he presented data from blue grama (Bouteloua gracilis) range to substantiate this relationship. Mott (1960) proposed that stocking pressure as animals per unit of available forage be utilizied for developing livestock production functions.

The approach of Mott (1960) was considered most realistic for the Wild Bill data. Thus, pounds gain per yearling day was regressed against stocking pressure with stocking pressure expressed as yearling days per 100 pounds of standing forage. Standing forage was taken as the weight of grasses plus 40% of the standing forb crop on caged plots at the end of the grazing season, mid September. A regression for the yearlings on the pastures for the years 1965-67 and a separate regression for the 1968-71 data were calculated. These regressions along with the plot of all the data points are shown in Figure 5 as Y_{D_1} and Y_{D_2}.

Two outlier points, one labeled 4-65 designating data for Pasture 4 in 1965 and 2-67 for Pasture 2 in 1967 are plotted on Figure 5 but were omitted from the regression analysis. For Pasture 4 in 1965, stocking pressure for most of the season was heavier than the average would indicate. The 2-67 outlier appears to be the result of an over estimate of standing crop for this pasture for this year.

Two outlier points for the 1968-71 data also were omitted from the regression analysis. These data points are labeled 6-68 for Pasture 6 in 1968 and 2-70 for Pasture 2 in 1970 and shown in Figure 5. There appears to be an under estimate of the herbage standing crop for Pasture 6 in 1968 (table 6) The data for data point 2-70 also appears to be a low estimate of standing crop (Fig. 2).

The regression of average daily livestock gain for 1965-67 (Y_{D_1}) and for 1968-71 (Y_{D_2}) have similar slopes and differ only in height of the lines.

$$Y_{D_1} = 1.65 - .18X \tag{7}$$

$$Y_{D_2} = 2.08 - .15X \tag{8}$$

Theoretically, the average daily gain per animal should reach a maximum and the curve should approach a zero slope at very low stocking pressures. The data points could be interpretted to show such a trend for stocking pressures below 2 yearling days per 100 pounds of forage, but for practical purposes, the linear relationship well represents the data throughout the general range of stocking pressure tested in the Wild Bill study. Stocking pressures were not heavy enough during the study to illustrate an expected steeper slope of the curve at high stocking pressures.

The livestock gain as pounds per 100 pounds of forage (Y_F) as shown in Figure 5 is calculated as Y_D times X or:

$$Y_{F_1} = 1.65X - .18X^2 \tag{9}$$

$$Y_{F_2} = 2.08X - .15X^2 \tag{10}$$

where X is the Yearling Days/100 pounds of forage. These relationships are plotted in Figure 5 and illustrate that the Y_{F_2} curve is much higher and the maximum shifts well to the right as compared to the Y_{F_1} curve. Thus, the potential of the animals for average daily gain (a) very much influences the point at which the maximum pounds of gain per 100 pounds of forage is achieved.

Hart (1980) has described the application of economics to these equations. The gross return (Y_R) per 100 pounds of forage can be calculated as price per pound of livestock gain (P) time Y_F as:

$$Y_{R_1} = P(1.65X - .18X^2) \tag{11}$$

$$Y_{R_2} = P(2.08X - .15X^2) \tag{12}$$

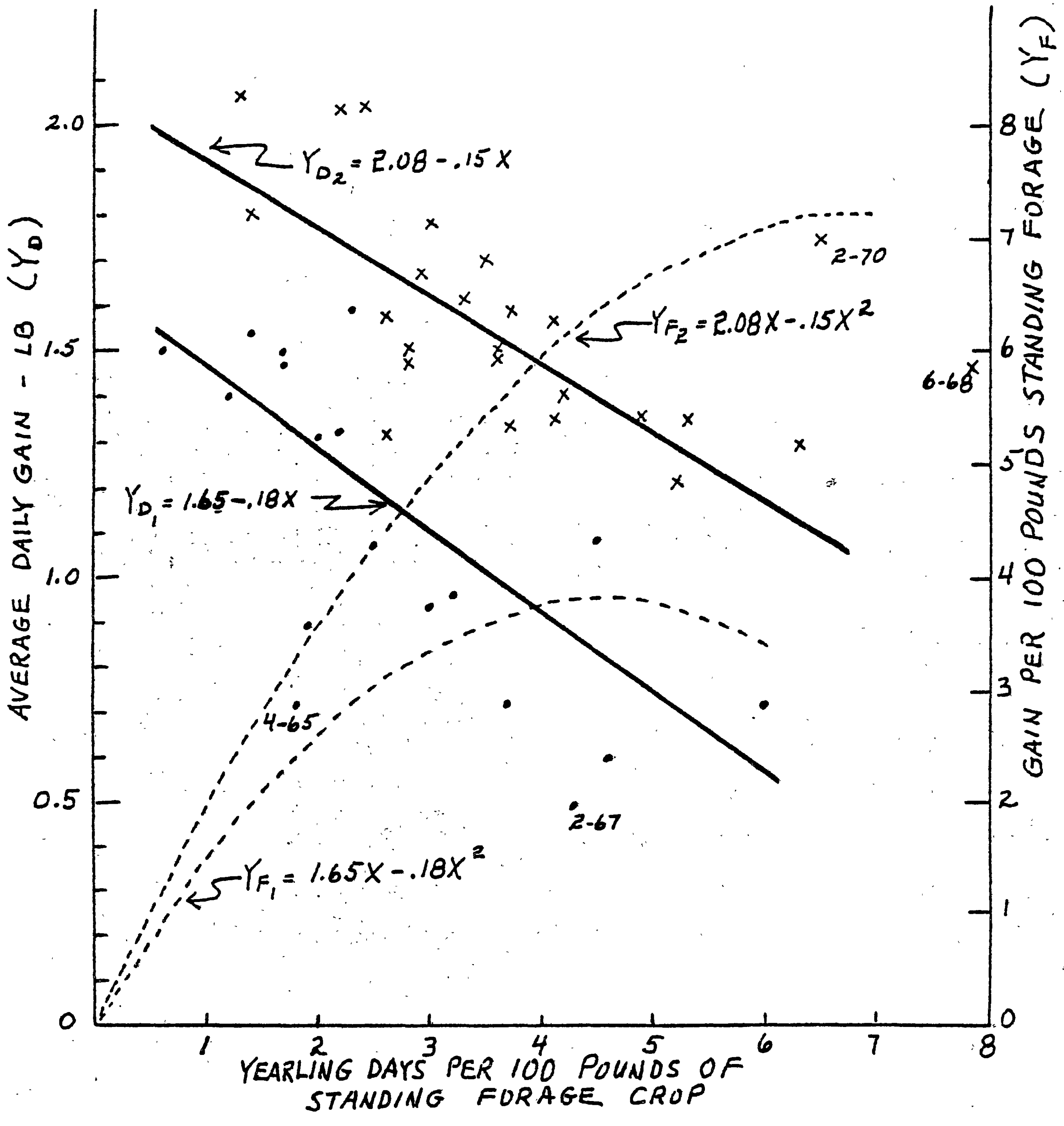

Figure.5.--Average daily gain versus yearling days per 100 pounds of standing forage on caged plots at the end of the grazing season for 1965-67 data (•) and 1968-71 data (x). The Y_F curves were calculated as Y_D times X.

The net return (Y_N) can be expressed as:

$$Y_N = Y_R - CX \tag{13}$$

or in general

$$Y_N = P(aX - bX^2) - CX \tag{14}$$

where C is the cost per yearling day, X is the yearling days per 100 pounds of forage, a is the potential average daily gain, and b is the slope of the regression line or decrease in average daily gain with each unit increase in stocking pressure. Setting the first derivative of equation (14) to zero identifies the maximum net return. Thus:

$$\frac{dY_N}{dX} = (Pa - C) - 2PbX = 0 \tag{15}$$

Equations (11) and (15) can be shown graphically. The curves of Figure 6 are plotted using the 1968-71 livestock production function (10) and assuming a price of \$.75 per pound for beef (P) and assuming two different levels of cost per yearling day. C_1 = \$.50 and C_2 = \$1.00 to illustrate the effect of costs per yearling on shifting the stocking pressure at which maximum net returns are received. If all operational costs were fixed and did not vary with the number of yearlings run, the maximum net return would correspond to the stocking pressure at which maximum gross returns are reached. As variable costs per yearling increase, however, as shown by the example in Figure 6, the stocking pressure at which net returns are the greatest shifts toward lighter stocking pressure.

The net return from livestock from range can, thus, be expressed in terms of equation (14). Net returns can be calculated for set stocking pressure goals as numbers of yearlings per 100 pounds of standing forage or set at a maximum net return by using equation (15). With the forage disappearance of 10 pounds per yearling day as shown by the Wild Bill data (table 14), each yearling day per 100 pounds of forage translates as equivalent to 10% utilization.

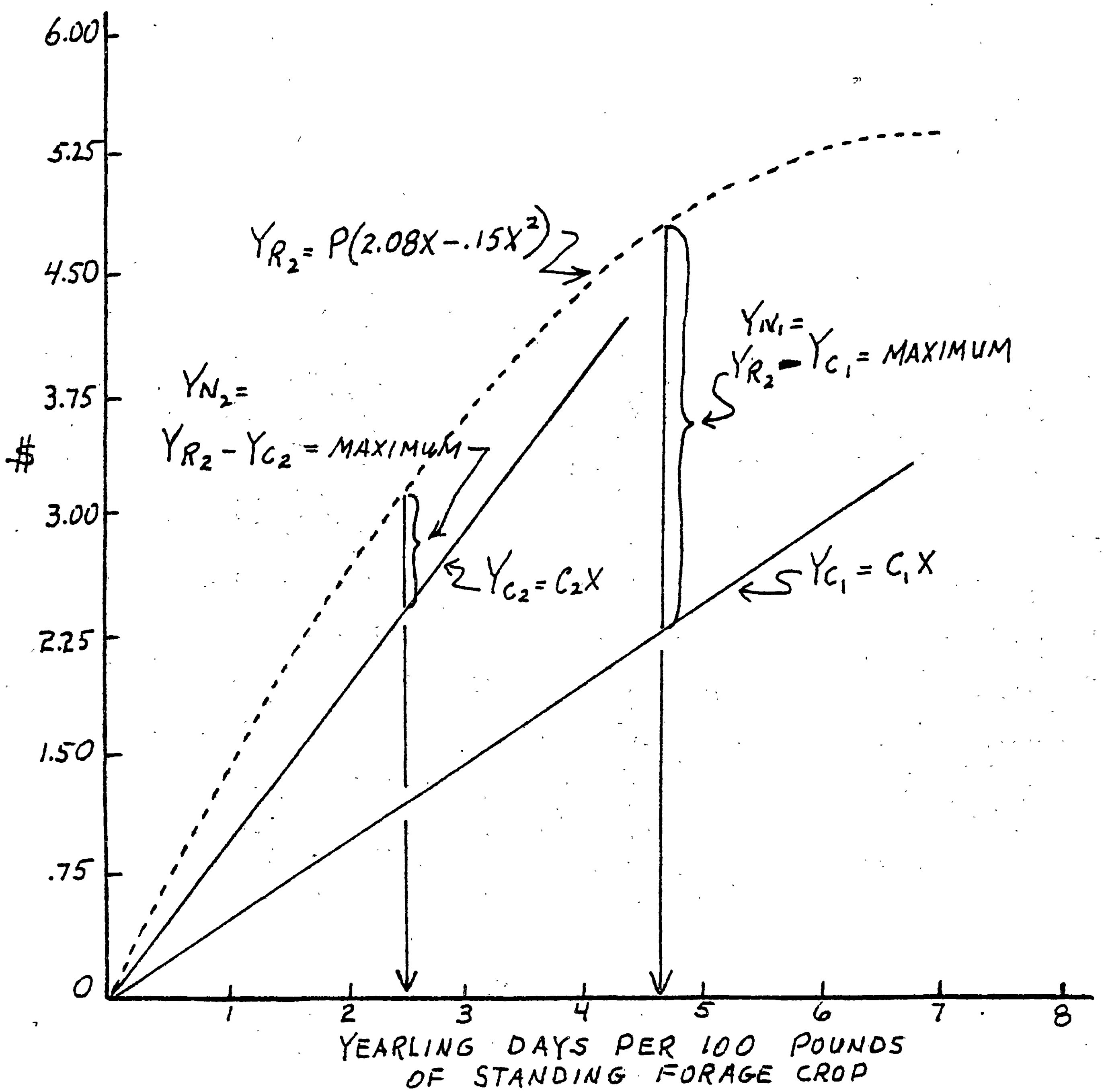

Figure 6.--Relationships of gross return to livestock (Y_{R2}) using the livestock production curve for the 1968-71 data from the Wild Bill Range, and stocking pressures as yearling days per 100 pounds of maximum standing forage at which net income (Y_N) is maximum for two levels of costs (C) per yearling day.

Thus, a stocking pressure of 5 yearling days per 100 pounds of forage is roughly 50% use of the peak standing forage crop.

Equations (7) and (8) provide the coefficients (a) and (b) for the livestock production estimates for ponderosa pine range comparable to the Wild Bill Range. The coefficient (a) is essentially the potential for average daily gain for a particular group of livestock. The coefficient (b) is the rate at which gain drops per unit increase in stocking pressure.

The solutions to equations (7) and (15) are all in terms of X as stocking pressure as yearling days per 100 pounds of peak standing forage crop as determined from caged plots. To express the Y values of the equations on a per acre basis rather than on the units of forage basis simply involves multiplying the Y values solved by the equations by the number of 100 pounds of peak standing forage crop which is produced by a particular treatment on a specific site. The mean number of 100 pounds of standing crop of forage produced per year on the Wild Bill pastures from 1964-74 are given in table 18.

The amount of peak standing crop of forage as given in table 17 for each pasture is less than the total standing crop data graphed in Figure 3 because forbs are only given 40% weight to the forage values given in table 17. Only for Pastures 1 and 2 where forbs made up a high part of the understory composition are the differences of major importance.

Table 18.--Units of 100 pounds of peak standing forage crop as a mean annual amount for Wild Bill pasture Number 1 to 6 over the period of 1964-74.

Pasture Number	Mean Basal Area sq ft/A*	Grass lb/A	Forbs lb/A	Grass Plus 40% Forbs lb/A	Number of 100 lb Units
1	0	852	218	939	9.4
2	0	476	600	716	7.2
3	24	463	72	492	4.9
4	34	375	80	407	4.1
5	52	246	78	277	2.8
6	63	287	46	205	2.0

SUMMARY

Confidence intervals for pasture mean annual peak standing grass and total understory herbage for the Wild Bill pastures generally varied between 20 and 50% of the mean. Most of the variation was within clusters and this suggests that the round, 9.6 square feet sample plot should be evaluated and compared with other plot sizes and shapes for efficiency to sample the Arizona fescue-mountain muhly understory vegetation as present on the Wild Bill Range.

Annual variation of peak standing grass crop on the Wild Bill pastures averaged maximums on the order of 60% of the 1964-74 mean and minumums of 30% below the 1964-74 mean. Thus, with a fixed stocking rate for livestock, a goal of 40% utilization for a mean production year would give about 60% use in the poorest year and about 25% utilization in the best year.

The relative ranking of a year for producing grass and total standing herbage for the Wild Bill pastures was expressed by equations using standing crop (dependent variable) as a percentage of the 1964-74 pasture means. The independent variables are seasonal precipitation as a percentage of the mean seasonal precipitation for 1964-74. Standing crop data for any year, therefore, could be evaluated as compared to a normal precipitation year.

A combination of fall, winter, and early spring precipitation best predicted standing crop on the wheatgrass pasture. Winter, spring, May plus June, and July plus August seasonal precipitation best estimated standing understory crop on the native pastures.

When grass standing crop data were adjusted for the effects of seasonal precipitation, a pattern of reduced grass crop following a year of heavy utilization was identified.

The clearing and thinning treatments reduced the percentage composition of grasses and increased forb composition. This change held throughout the 1964-74 study. The species of forbs which dominated the bare areas created when Pastures 1 and 2 were cleared did change over the 1964-74 period.

The 1964-74 mean standing understory crop for the Wild Bill pastures follow a general curvilinear decrease with increasing basal area of ponderosa pine. The mean data for Wild Bill should represent near normal precipitation conditions and vegetation response to pine harvest and thinning with slash piled and burned and grazed at a moderate to light utilization following the timber treatments.

A regression analysis of utilization of forbs versus utilization of grass showed that 40% of the forb component of the understory vegetation on the Wild Bill pastures was considered as contributing to the forage supply.

Standing crop disappearance associated with yearlings grazing on the Wild Bill pastures during the late May to mid September grazing season averaged 10 pounds per yearling day. This equates to about 2% of the yearling body weight per day or 600 pounds per animal unit month.

Yearling average daily gain (Y_D) was determined to be a linear function of stocking pressure (X) expressed as yearling days per 100 pounds of peak standing forage crop. For yearlings with a potential to gain 2 pounds per day, the average daily gain (Y_D) function is:

$$Y_D = 2.08 - .15X$$

The yearling production expressed as pounds gain per 100 pounds of peak standing forage (Y_F) is:

$$Y_F = 2.08X - .15X^2$$

where X is stocking pressure as yearling days per 100 pounds of forage. One yearling day per 100 pounds of forage roughly equates to a 10% unit of utilization.

Gross economic return may be calculated as price per pound (P) times Y_F from above, or:

$$Y_R = P(2.08X - .15X^2)$$

Net economic return (Y_N) is calculated as:

$$Y_N = P(2.08X - .15X^2) - CX$$

where C is cost for interest, feed, labor, per yearling day. The stocking pressure (X) at which maximum net return is attained is calculated by setting the first derivative of $Y_N = 0$, thus:

$$\frac{dY_N}{dX} = (2.08P - C) - .30PX = 0$$

The solutions for equations given under 10-13 above are all in terms of 100 pounds of standing forage crop. Multiplying by the number of 100 pounds of forage per acre converts the solutions to a per acre basis. The mean number of 100 pounds of peak standing forage for the Wild Bill pastures for the 1964-74 period are:

Pasture No.	Mean Basal Area Sq. Ft/A	Number of 100 lb Units of Forage
1	0	9.4
2	0	7.2
3	24	4.9
4	34	4.1
5	52	2.8
6	63	2.0

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Appendix A-Scientific and Common Names of Common Plants Found on the Wild Bill Range

Grasses

Agropyron cristatum	crested wheatgrass
Agropyron intermedium	intermediate wheatgrass
Blepharoneuron tricholepis	pine dropseed
Carex spp.	sedges
Dactylis glomerata	orchard grass
Festuca arizonica	Arizona fescue
Hordeum jubatum	foxtail
Muhlenbergia montana	mountain muhly
Poa fendleriana	mutton bluegrass
Sitanion hystrix	squirreltail

Forbs

Chenopodium spp.	lambs quarter
Cirsium spp.	thistle
Conyza schiedeana	horsetail
Erigeron divergens	daisy
Erigeron flagellaris	daisy
Lupinus sp.	lupine
Potentilla hippiana	cinquefoil
Potentilla thurberi	cinquefoil
Verbascum thapsis	mullein
Senecio spp.	groundsel
Vicia americana	vetch

Shrub

Ceanothus fendleri	Fendler buckbrush or Fendler ceanothus

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